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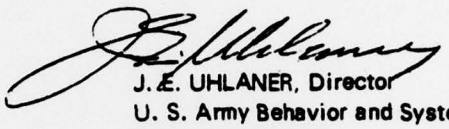
FOREWORD

The research described in the present report is part of BESRL's program under the direction of the Combat Systems Research Division to develop methods of improving performance that can be applied to a variety of complex Army systems. Because of the importance of rotary-wing flight to the Army and the severity of the difficulties that Army pilots face, initial effort has been directed to the problems of helicopter pilot performance at nap-of-the-earth altitudes. Since helicopter missions under wide-intensity warfare conditions will have to be performed at extremely low levels, significant problems (some of which are described here) arise for the helicopter aircrew, particularly in terms of the visual factors affecting their performance.



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ATTITUDES OF EXPERIENCED HELICOPTER PILOTS TO NAP-OF-THE-EARTH FLIGHT

BRIEF

Requirement:

To determine how experienced helicopter pilots view nap-of-the-earth (NOE) flight operations and the factors that affect these operations.

Procedures:

Twenty-two pilots from the 1st Squadron, 9th Cavalry, based at Ft. Hood, were individually interviewed for 45 minutes.

Findings:

Many pilots experienced a high degree of fatigue and stress while flying at low levels, particularly at night time. The primary causes are:

1. Because potential terrain obstacles like trees and power lines must be avoided, an excessive amount of visual scanning is required of the pilot.
2. At low levels, pilot response to potential emergencies must be quicker than at higher altitudes.
3. Because of terrain obstacles, low level flight is inherently more hazardous than flight at altitude; this produces increased pilot tension.
4. Systematic training in low level flight operations tends to reduce stress.
5. Terrain familiarization is an essential element in satisfactory low level flight.

Implications:

1. Because the low level flight situation is significantly different from that of altitude flight, the Army should, in developing its NOE training program, investigate the special perceptual and motor cues required for this type of training.

2. Since much fatigue results from the need to scan peripherally, a rearward viewing device should be developed.

3. Since pilots in a mid-intensity warfare environment may not have the opportunity to familiarize themselves with their area of operations by flying over it, research should be performed to determine the most effective means of familiarizing the pilot with terrain features prior to their performing missions.

It is apparent from these interviews that NOE flight presents significant difficulties to the helicopter pilot. BESRL personnel intend to continue researching these problems with special emphasis on the recommendations above.

ATTITUDES OF EXPERIENCED HELICOPTER PILOTS TO NAP-OF-THE-EARTH FLIGHT

THE PROBLEM OF NAP-OF-THE-EARTH FLIGHT

The EFFECTIVE AIRCREW PERFORMANCE work unit of the Behavior and Systems Research Laboratory (BESRL) was recently asked to investigate reports that nap-of-the-earth (NOE) daytime flight was excessively fatiguing and stressful. (One comment quoted was, "One hour of NOE is equivalent to 8 hours of combat flying".) The major questions that BESRL was asked to answer were: Are these reports correct? If so, what are the causes? What can be done about it?

Since fatigue and stress are largely subjective experiences, the logical initial approach was to ask helicopter pilots flying NOE how they felt about the matter. Not that interviews would solve the problem (if one existed), but they might suggest directions in which to pursue further research.

Twenty-two pilots from the 1st Squadron, 9th Cavalry, based at Ft. Hood, were each interviewed for 45 minutes during the period June 7 - 9, 1972. Twenty of the pilots were Vietnam veterans with an average total number of 1377 helicopter hours, 1025 of these flown in Vietnam. The two (2) non-Vietnam pilots had an average of 240 flight hours.

IS NOE OVERLY FATIGUING AND/OR STRESSFUL?

In the opinion of these pilots, the answer to this question is YES.

72% said: Low level (LL) daytime flight is more demanding than daytime flight at altitude.

95% said: Night time low level flight is much more demanding than daytime low level flight.

50% said: Fatigue and/or stress in low level flight is a significant problem to pilots.

The following is a typical sample of the comments made:

"Low level daytime flight requires infinitely more attention; for that reason it's more difficult . . . (requires) visual scanning constant attention to the aircraft, no real opportunity to relax . . .

"Night time low level is the most demanding experience I've had in an aircraft; there's an increased amount of terrain watching; it's

increasingly more difficult to navigate . . . you have to stay on the map constantly . . . I prefer not to fly at night if I can avoid it . . ."

What these comments mean is that although low level flight is not a stressful situation for all pilots, enough of them feel that it is to make the situation merit further investigation.

This is not to suggest, however, that pilots do not perform their low level missions adequately, even under conditions of fatigue and stress. However, the possibility of error and near-accidents is increased by these conditions.

Pilots reported that the duration of their low level missions ranged from 30 minutes to 3 hours, the average being 1 to 1-1/2 hours. Strictly from a time standpoint, therefore, these missions should not overly fatigue the pilot; many Vietnam veterans flew much longer missions in Southeast Asia. If NOE flights are fatiguing, it must be for other reasons.

One possibility is that low level flight is inherently taxing. These missions often require flying at altitudes ranging from 0 to 50 feet above the highest terrain, although part of the mission may be at altitude (e.g., 800 to 1000 feet). It would appear from these conversations that NOE is not arbitrarily defined as a specific altitude; the tactical requirement determines the altitude. Pilots differ in terms of what they consider low level flight, some pilots defining it as 0 feet above the highest obstacle, others at altitudes up to 300 feet. The terms NOE and LL are often used interchangeably, although NOE suggests a lower flight level than low level. Apparently within the constraints of the mission, pilots are free to select the specific altitude at which they feel most "comfortable" (a phrase often used by Army aviators).

CAUSES OF FATIGUE AND/OR STRESS

Given that for many pilots low level flight (both in daytime and at night) is more stressful than altitude flight, the next question is WHY? There appear to be three major reasons:

1. The amount of visual scanning required of the pilot, particularly peripheral scanning, is much greater at low level. The existence of terrain obstacles like trees and power lines makes it necessary for pilots to be constantly hyper-alert to avoid accidents such as "blade strikes" (cutting trees with rotor blades). Since present operational helicopters contain no terrain obstacle-sensing equipment, the pilot must function as his own radar warning system. In most cases he develops a systematic scan pattern, his gaze alternating regularly between instruments and windscreen. His co-pilot (and crew chief in those aircraft that fly a third personnel) reduce the visual burden somewhat, but not significantly.

2. At low levels, pilot response to potential emergencies such as engine failures must be much quicker than at higher altitudes. The pilot must, therefore, be much more alert; he must be more "keyed up" to anticipate potential problems.

3. Because of terrain obstacles, low level flight is inherently more hazardous than flight at altitude; this produces increased pilot tension. All pilots are trained to be safety conscious, but some seem preoccupied with the safety factors involved in low level flight.

These three factors are amplified in night flights because visibility is substantially less. A few pilots in the sample interviewed reported that they were quite "uncomfortable" flying at night and dislike it intensely.

One effect of these feelings is that pilots who are somewhat "leery" of low level flight may tend to fly somewhat higher and slower than their companions (still within mission requirements, of course).

It is difficult even for an expert to differentiate between fatigue and stress. If we define fatigue as produced by work requirements (mainly additional scanning), and stress as tension resulting from awareness of potential hazards, then pilots consider that stress contributes to fatigue and may in fact be its major component.

Almost all the pilots felt that increasing low level flight experience tends to reduce the severity of stress reactions. On the other hand, however, increased low level experience probably reduces work requirements only minimally, because in this type of flight the pilots rely more on direct ("eyeball") scanning of the terrain ahead than on their instruments. This practice is likely to continue even when the sophisticated sensing devices presently under test become operational, because it is more natural in daytime low level flight for pilots to rely on their own eyes than on instruments (except under instrument conditions). It is the inability to see the terrain ahead that makes low level night flight so demanding. At night, therefore, the new sensing devices will be useful, but probably will be minimally used in daytime.

Environment, Vertigo and Disorientation. A review of the literature (performed by BESRL before the interviews)[1] indicated that a number of environmental factors might contribute to fatigue, if not to stress: noise, heat, vibration, rotor flicker, exhaust fumes. None of these was considered by pilots to be a critical factor. The APH-4 helmet dampens noise very well and is heartly approved by pilots. Pilots could experience heat as a problem if the Cobra's Environmental

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[1]Meister, D. and deHaan, H. J., Preliminary Analysis of Factors Influencing Low-Level Navigation. Unpublished Memorandum Report, U. S. Army Behavior and Systems Research Laboratory, 31 March 1972.

Control Unit malfunctions (a few pilots reported Vietnam experiences under these circumstances in which heat became unbearable), but in Huey's one can always open windows and doors. Vibration poses no problems; if it is excessive, it suggests only that the aircraft is malfunctioning. Present operational helicopters have eliminated what might once have been the problem of gas exhaust. A few pilots reported rotor flicker as a difficulty, but again it has only minor significance.

Since the literature has discussed vertigo and visual illusions as phenomena affecting helicopter pilot performance, pilots were asked about these also. Most pilots have experienced at least one episode of vertigo or visual illusion during their flying careers, but these episodes appear of relatively little consequence in their effect on low level flight. When vertigo occurs, it is primarily in instrument training. Visual illusions may occur at night or in poor visibility conditions but are not specifically associated with low level flight.

For example, the most unusual episode related by a pilot involved a night combat mission over Vietnam. It appeared to the pilot that he was being overtaken by another helicopter in the vicinity. He finally realized that he was trying to fly away from the shadow of his own aircraft reflected by the flares dropped to illuminate the target area. Other visual illusions are produced by staring at lights on the ground or at the lights of other aircraft. The literature, therefore, is correct about the frequency of visual illusions or vertigo, but these experiences were not considered by the pilots as a significant problem.

Disorientation (a phrase used more by pilots than its common equivalent, "getting lost") occurred primarily when the pilot was relatively unfamiliar with the terrain he was overflying. The duration of such episodes was, however, quite short--1 to 2 minutes, usually--and the strategy adopted by pilots flying low level was to climb, scan the area from the higher altitude, and then descend to find their checkpoint. Most instances of disorientation were a matter of not being able to report the 6-digit ground coordinate when required. Disorientation occurred most frequently when the terrain was flat and lacked distinctive features.

Navigation at low level is a problem to some pilots, but the extensive familiarization which is part of the training given at Ft. Hood prior to flying missions tends to minimize navigation difficulties. Terrain familiarization is an essential element in low level navigation and pilots do not feel completely confident of their navigation ability until they have learned the terrain. A problem may therefore arise in mid-intensity warfare if the pilot cannot fly the terrain to familiarize himself with it.

Cockpit Factors. With regard to cockpit factors, the field of view in the Huey and Cobra was felt by pilots to be adequate for most low level operations (an important observation in terms of the amount of visual scanning that goes on). Some problems were noted with the

presence of the rocket-sighting device located in the Cobra, which does impede the command pilot's vision. The location of some instruments (e.g., radios) on the right of the pilot is undesirable because it requires him to switch hands on his controls to activate these instruments; but again this is not a critical problem. One or two Huey pilots indicated that if their windshield wipers were used during rainfall, the dirt and sand accumulated by the wiper would scratch the windscreen, degrading its usefulness for night flight.

As far as cockpit improvements are concerned, as they reflect the exigencies of low level flight, one suggestion made by a number of pilots is worth mentioning. Because of the difficulty of looking behind oneself at the tail rotor, putting the aircraft down in a confined space surrounded by trees presents substantial difficulties. The desirability of a backward view leads to the idea of placing a rear view mirror in or on the aircraft. It is impossible without some testing to determine the technical feasibility of such an equipment, but if it were possible to increase peripheral and rearward vision in the helicopter, it is likely that the amount of peripheral scanning required of the pilot (and hence his work effort) would be reduced.

TRAINING FOR LOW LEVEL FLIGHT

For those pilots who had to fly low level in Vietnam, no special training was provided before they flew those missions. At present, however, the Army recognizing the need for such training is preparing to develop the required curriculum.

The importance of such training was emphasized by all the pilots interviewed in this study. Although they recognize the difficulties inherent in low level flight, they feel that many of these can be overcome by a systematic training program. About half the pilots interviewed had received such training, particularly for night flight, at Ft. Hood, prior to their flying low level missions. This training consisted of flying the inexperienced pilot with a pilot who was more experienced in low level night operations, and progressively reducing the altitude at which the trainee flew until he felt "comfortable". In this way, the flight altitude was progressively reduced until the pilot was flying NOE. Currently, too, all pilots at Ft. Hood must pass a low level proficiency test which simulates operational combat conditions.

The pilots interviewed hypothesized that an inexperienced pilot would indeed feel fatigued and stressed by low level flight, but that these feelings would be reduced with increasing training and terrain familiarization. Conceivably, those pilots whose reports of undue fatigue and stress conditions had led to these interviews had not had sufficient low level training and experience, or, if they had, had not maintained their proficiency. Many pilots felt that some proficiency and confidence would be lost if the pilot had to lay off low level flight for a while.

CONCLUSIONS

1. Low level flight is inherently fatiguing and stressful, more so at night than in daytime. Sophisticated night vision and obstacle sensing devices (e.g., low light level TV, radar, IR, HUD) should reduce these difficulties, but will probably never completely eliminate them.

Until such devices are available, training and experience in this type of flight will be the only means of reducing fatigue and stress. Even after such devices are available, considerable training will have to be given to pilots to enable them to make effective use of this equipment.

It appears reasonable that no one should be permitted to fly low level without some form of systematic training and testing like that given at Ft. Hood. At the same time, however, the Army should recognize that the special demands of low level flight create a vastly different working environment for the pilot. Visual recognition tasks involved in navigation, terrain following, and terrain avoidance are significantly different when performed at low level than they are at altitude. Research on the perceptual/motor inputs and outputs required for effective low level flight should, therefore, proceed along with the development of low level training. Without such research, the required training will not be as effective as it should be.

2. Since much of the sheer effort required of the pilot involves peripheral scanning, a device might be developed which makes this easier for him. The rear view mirror suggested by the pilots themselves is a good start in that direction. The principle might be taken up and expanded by developing a device with special lens characteristics which retain the wide field of view needed by the pilot but concentrates the image in the forward cone of his vision.

3. An essential element in low level flight appears to be the pilot's familiarity with the terrain he is overflying. Much of the pilot's special training at Ft. Hood involved becoming familiar with the immediate area.

Even when sophisticated display equipment becomes available, terrain familiarization (recognition) will be required. Radar and IR merely permit the pilot to "see" more efficiently; he will still have to <u>recognize</u> what he sees and relate his perceptions to a map coordinate system. In a mid-intensity situation, moreover, it cannot be expected that the pilot will be entirely familiar with his terrain before he begins his mission.

An important area of research is therefore to determine how to maximize pre-mission ground briefings to enable the pilot to navigate low level more effectively, despite restricted opportunities to familiarize himself with the area of operation. Questions such as the following need answers that can be provided only by research:

a. What should the pilot be familiarized with, only selected terrain features of a given area, the total area of operation, or only a specified mission course?

b. What is the most effective means of familiarization: conventional maps, terrain models, still photographs taken by reconnaissance planes, or motion pictures of the terrain?

c. Given that the pilot must fly NOE at night, should the photographs used in terrain recognition be taken in daylight or at night and at what altitude?

d. How much familiarization training must be given? How effective will that training be?

Such research should lead to the development of a standard briefing procedure and materials for ground terrain familiarization.